Observing Gravitational Waves from the Next Nearby Core-Collapse Supernova

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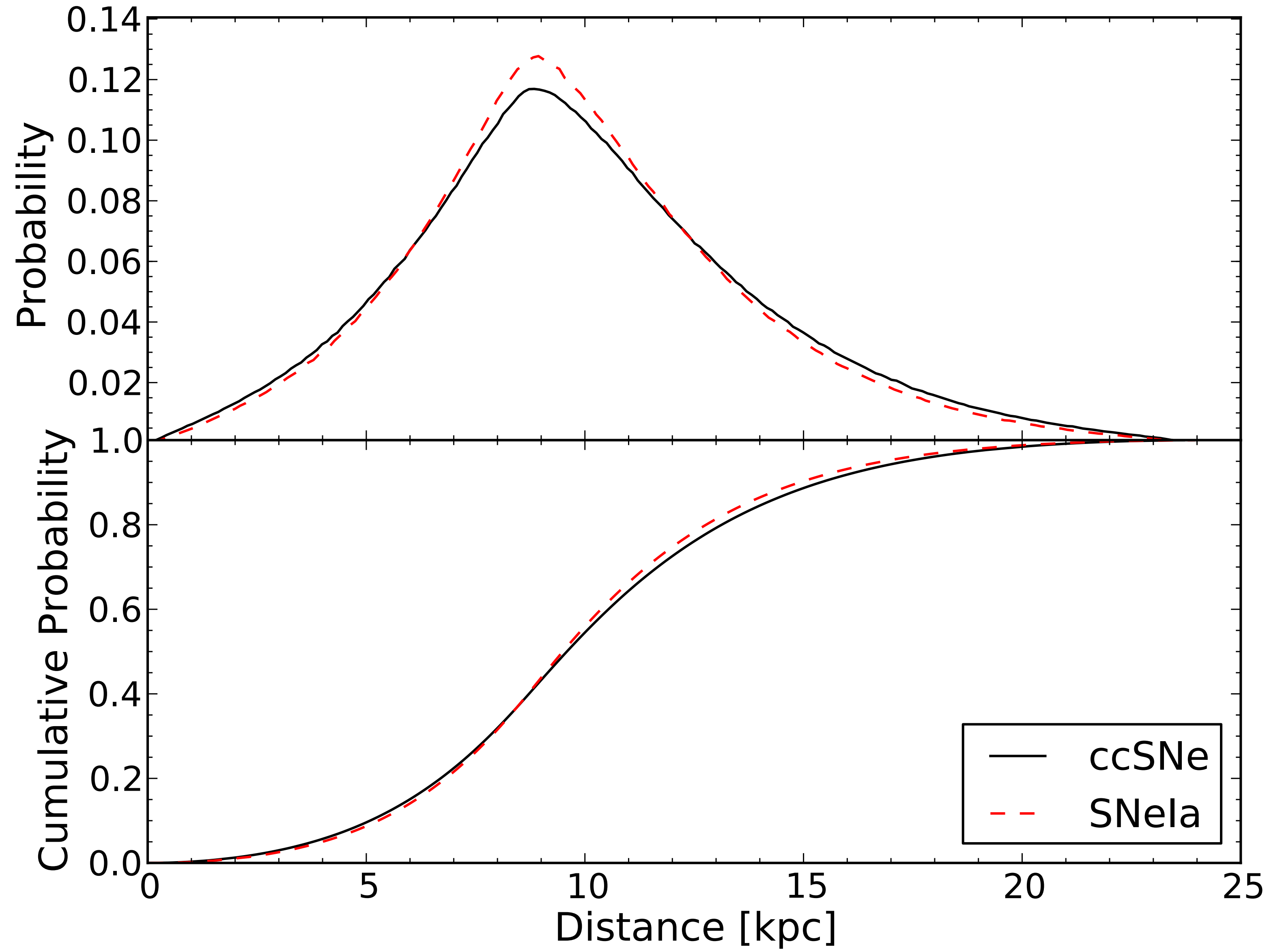
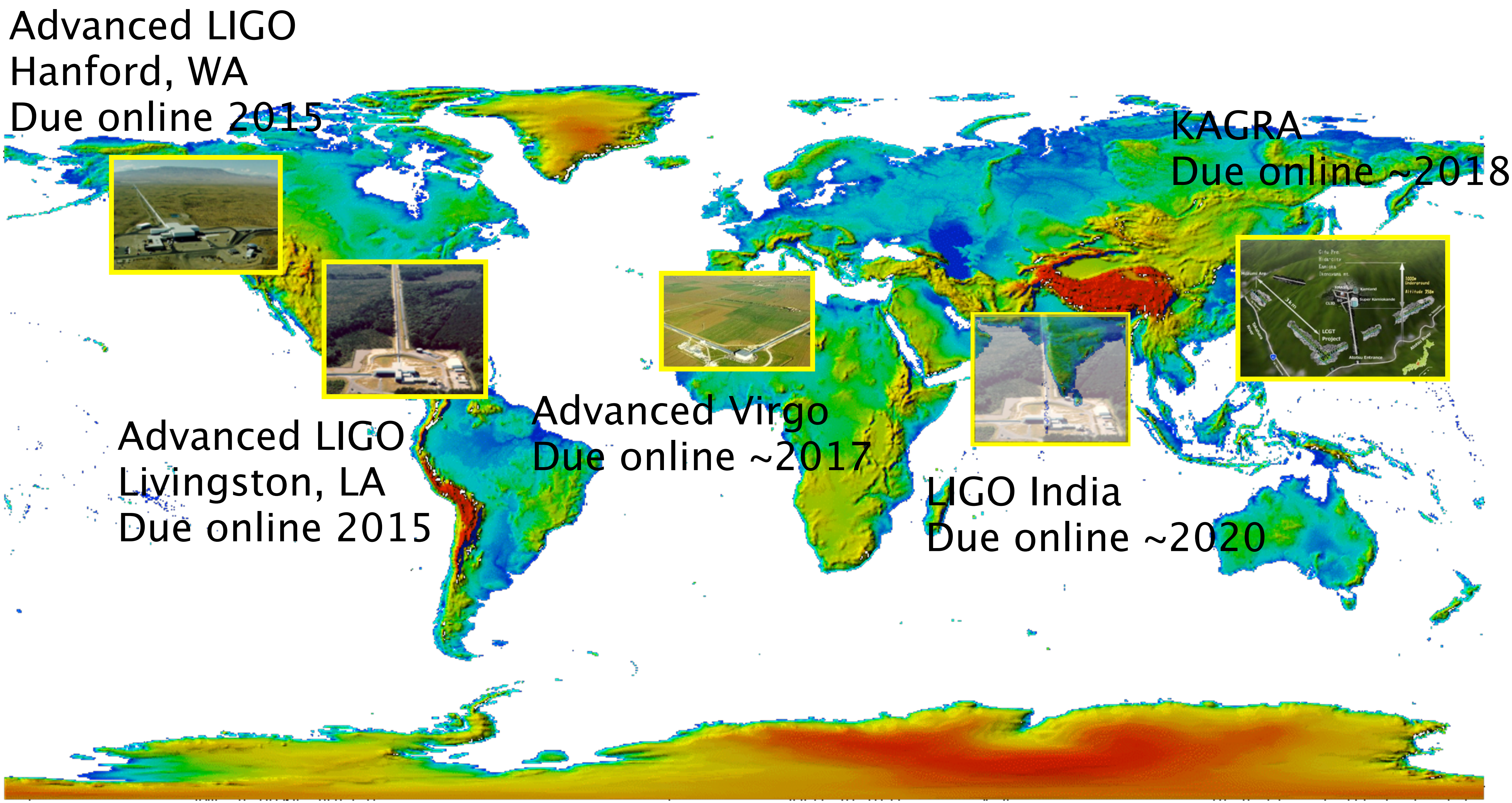
Prospects for Nearby Core-Collapse Supernovae

- Important galaxies for CCSN rate in Local Group (CCSNe/100yr)
  - Milky Way (0.5-2.5)
  - LMC (0.1-0.5)
  - NGC6822 (~0.04)
  - M31 (0.2-1.2)
- M82 @ 3.52Mpc with (3.0-13.0) CCSNe/100yr
- CCSNe most likely to be ~10kpc from galactic center.



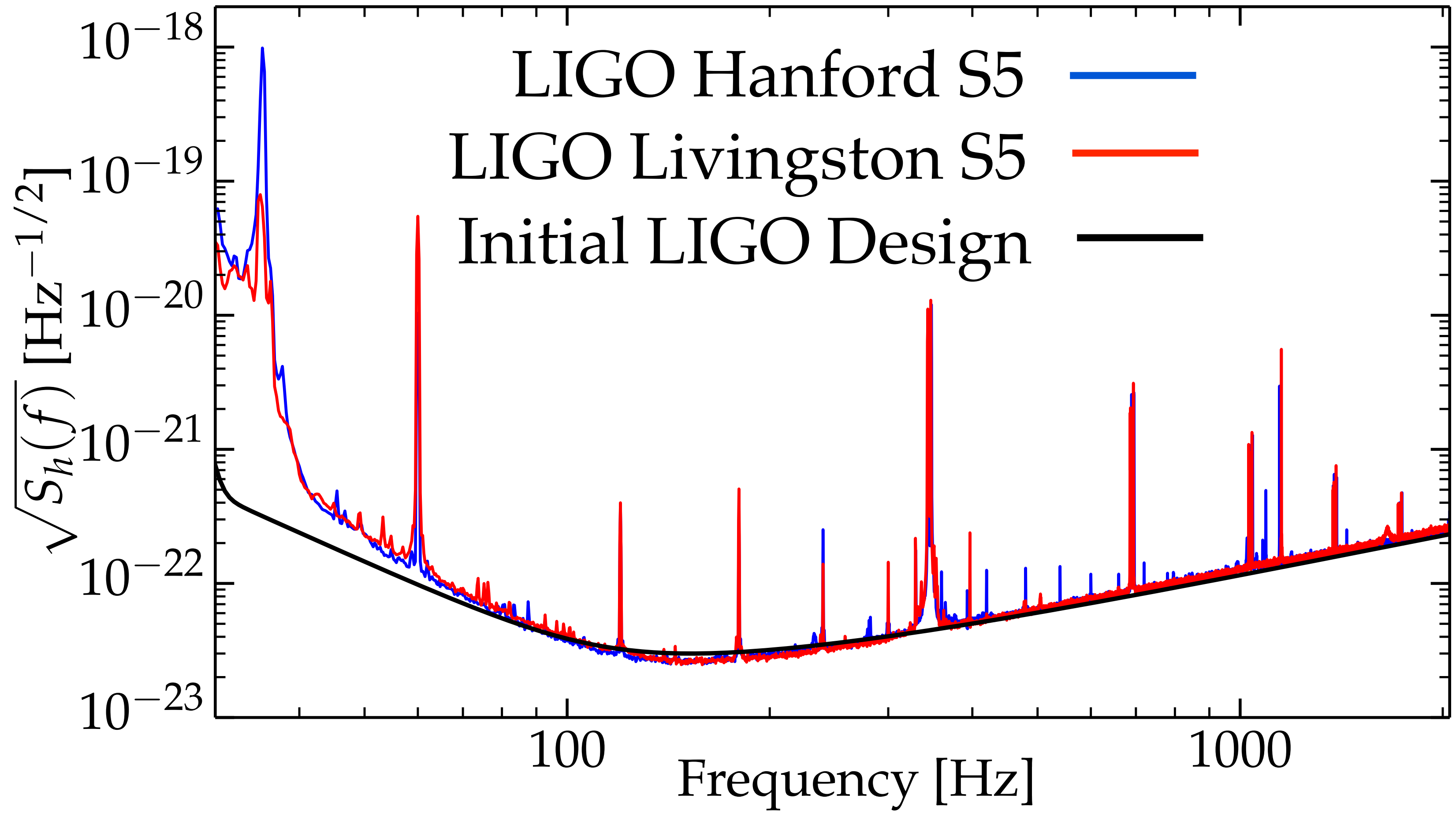
Adams+13

The Advanced Detector Network



Challenges in Detecting CCSNe

- Low event rate for aLIGO.
- Duty cycle not optimal.
- Non-Gaussian and non-stationary detector noise.
- Can't predict exact GW signal expected robustly.

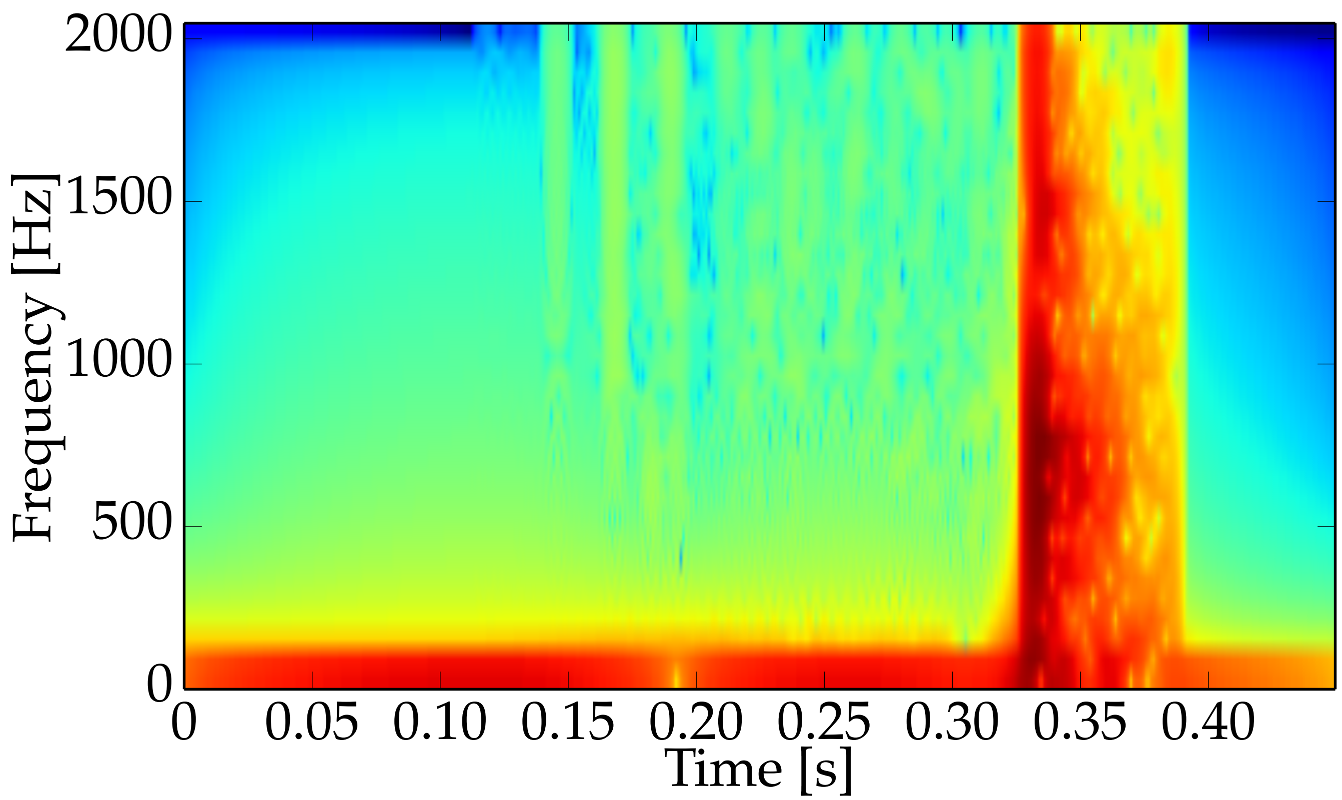


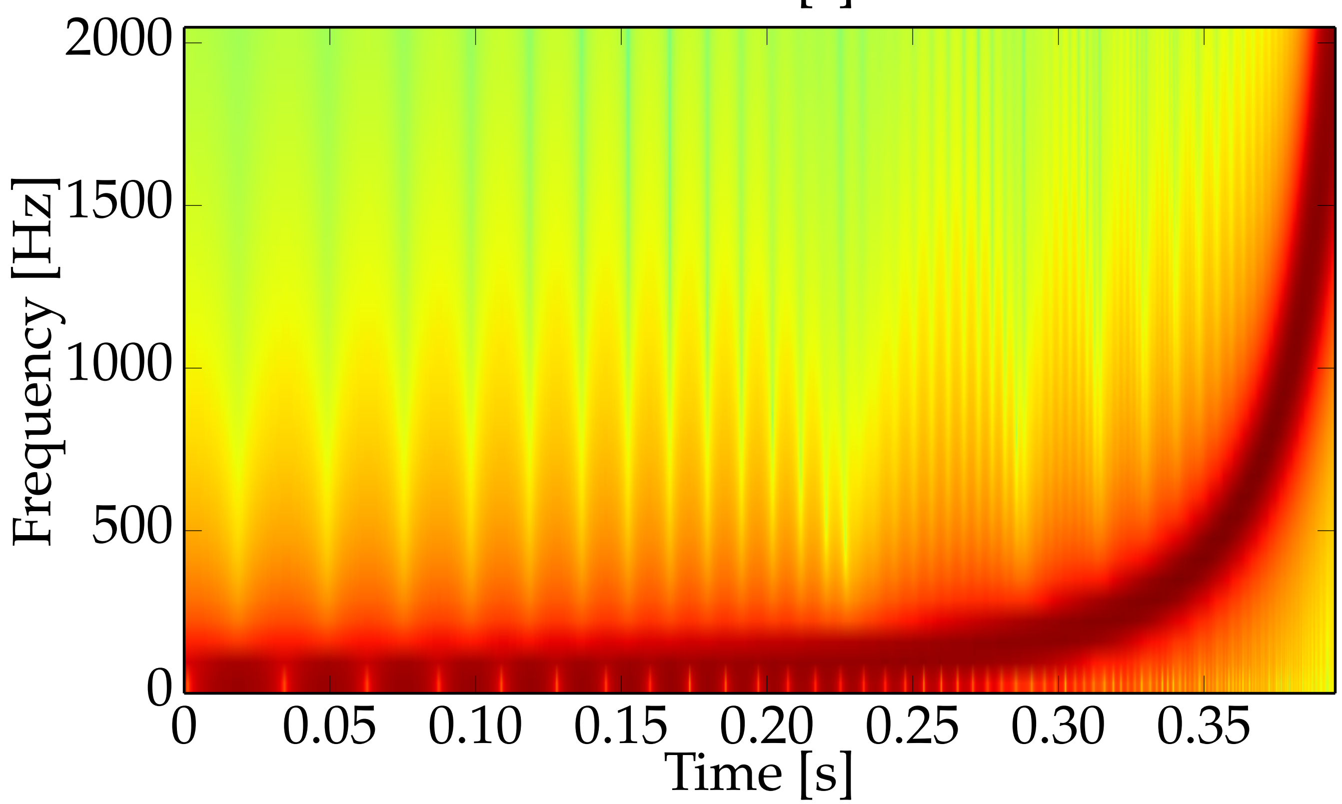
Detector	S5y1 (Nov 05-Nov 06) Duty Cycle
H1	72.8%
L1	59.3%

Abbott+09,Phys.Rev.D80:102001

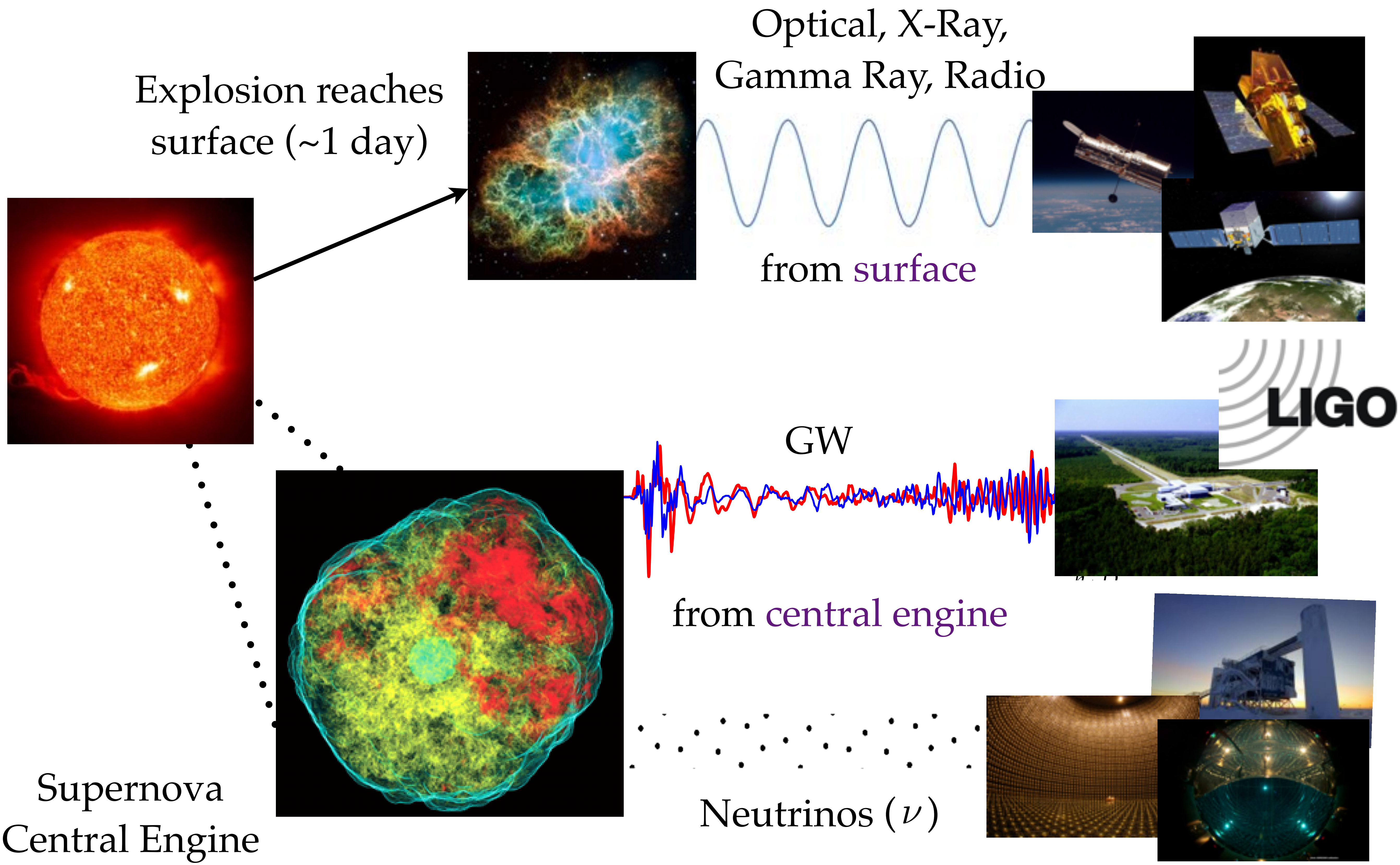
The Excess-Power Search

- Uses time-frequency signal content.
- Optimal for unmodelled signals.
- Does data contains excess-power than expected from noise?
- Increase accuracy by reducing `on-source' region (OSR).
- X-Pipeline (Sutton+09) and Coherent WaveBurst (Klimenko+08).

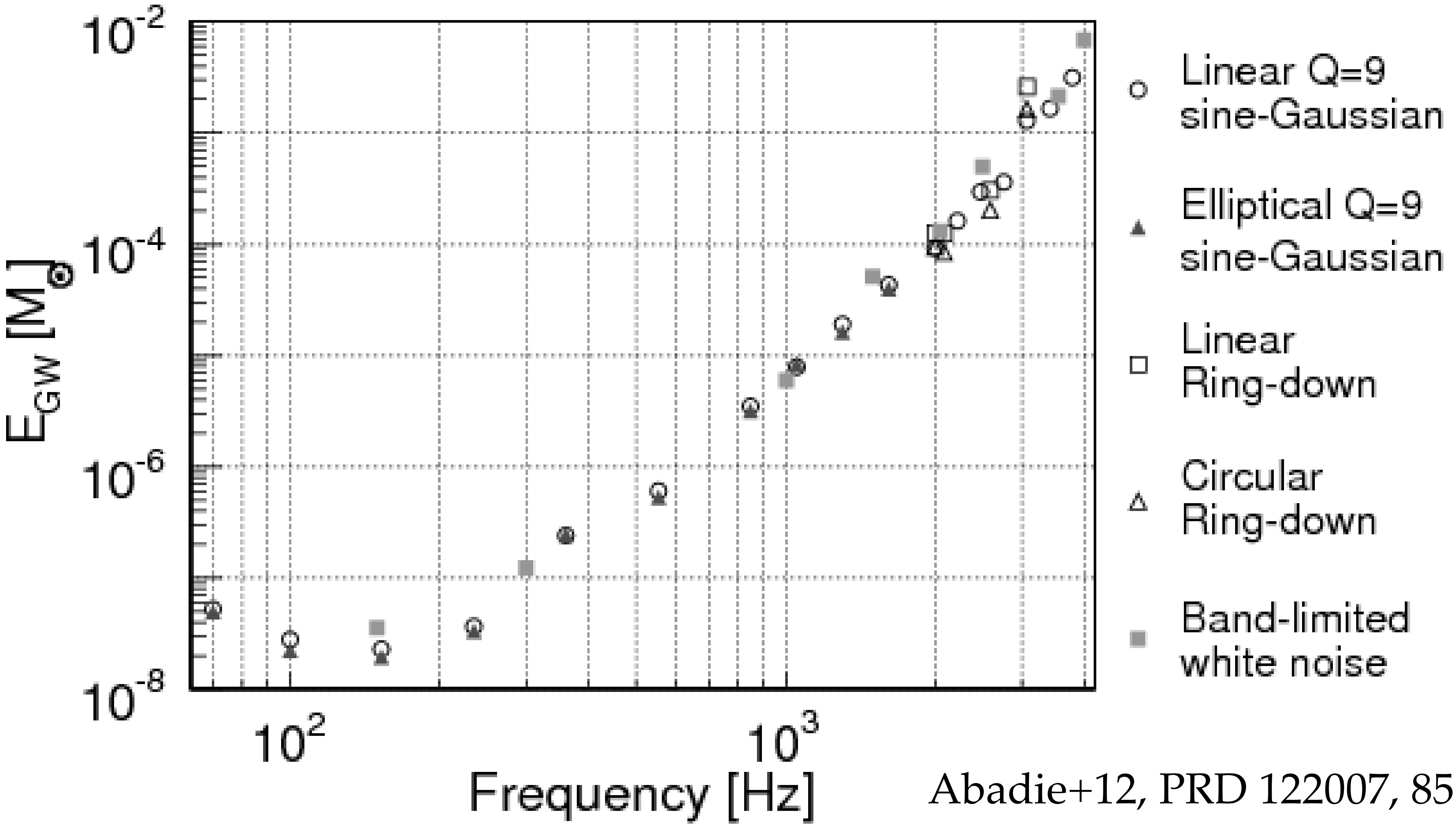




Utilizing Multi-Messenger Observations

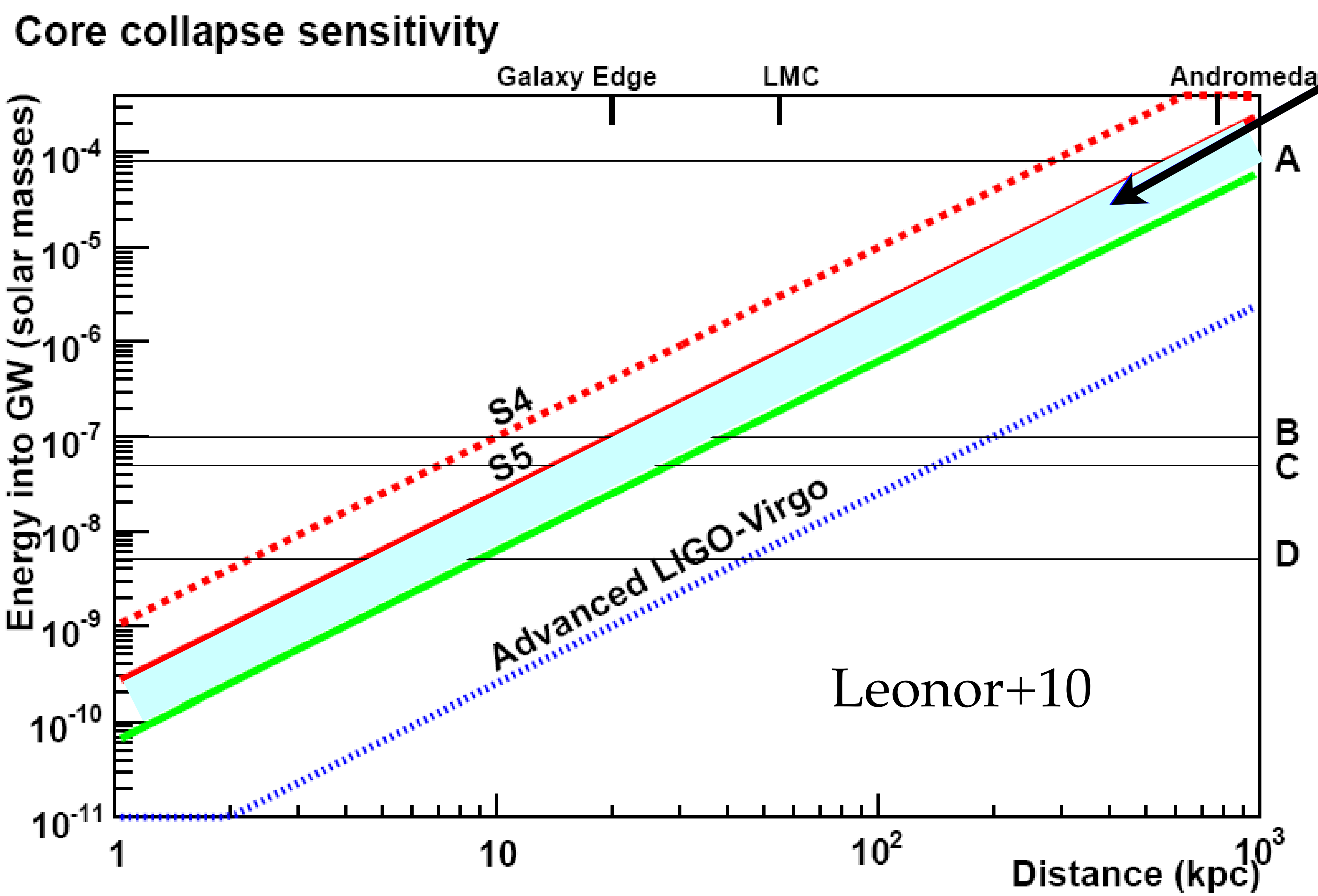


GW Searches for CCSNe so far



Abadie+12, PRD 122007, 85

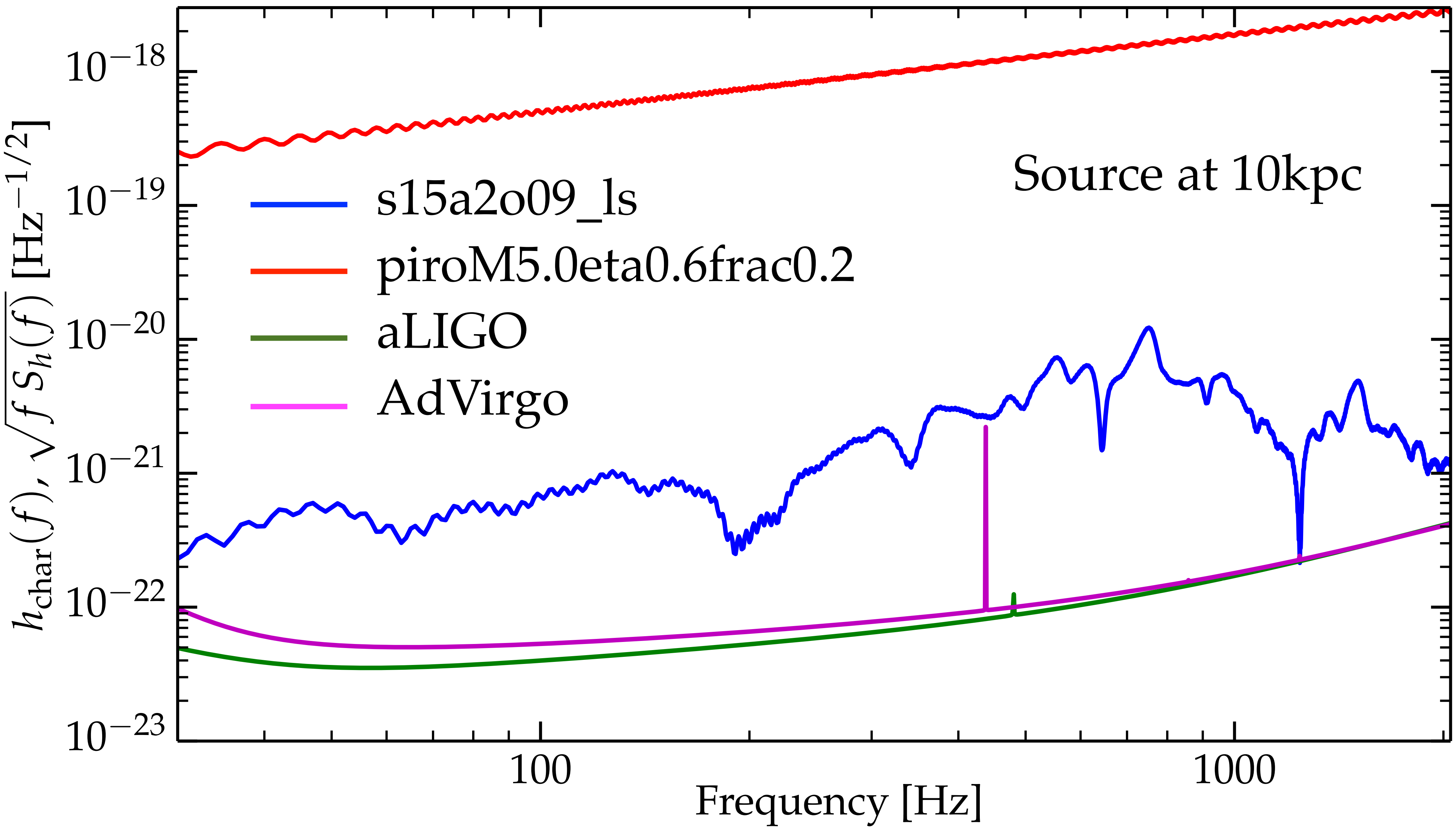
A Joint GW-ν Search for CCSNe



Additional region probed by coincident neutrinos

- Collaboration with IceCube/LVD/Borexino.
- Additional coincidence test - operate both networks at lower detection threshold.
- Doubles E_{GW} sensitivity.

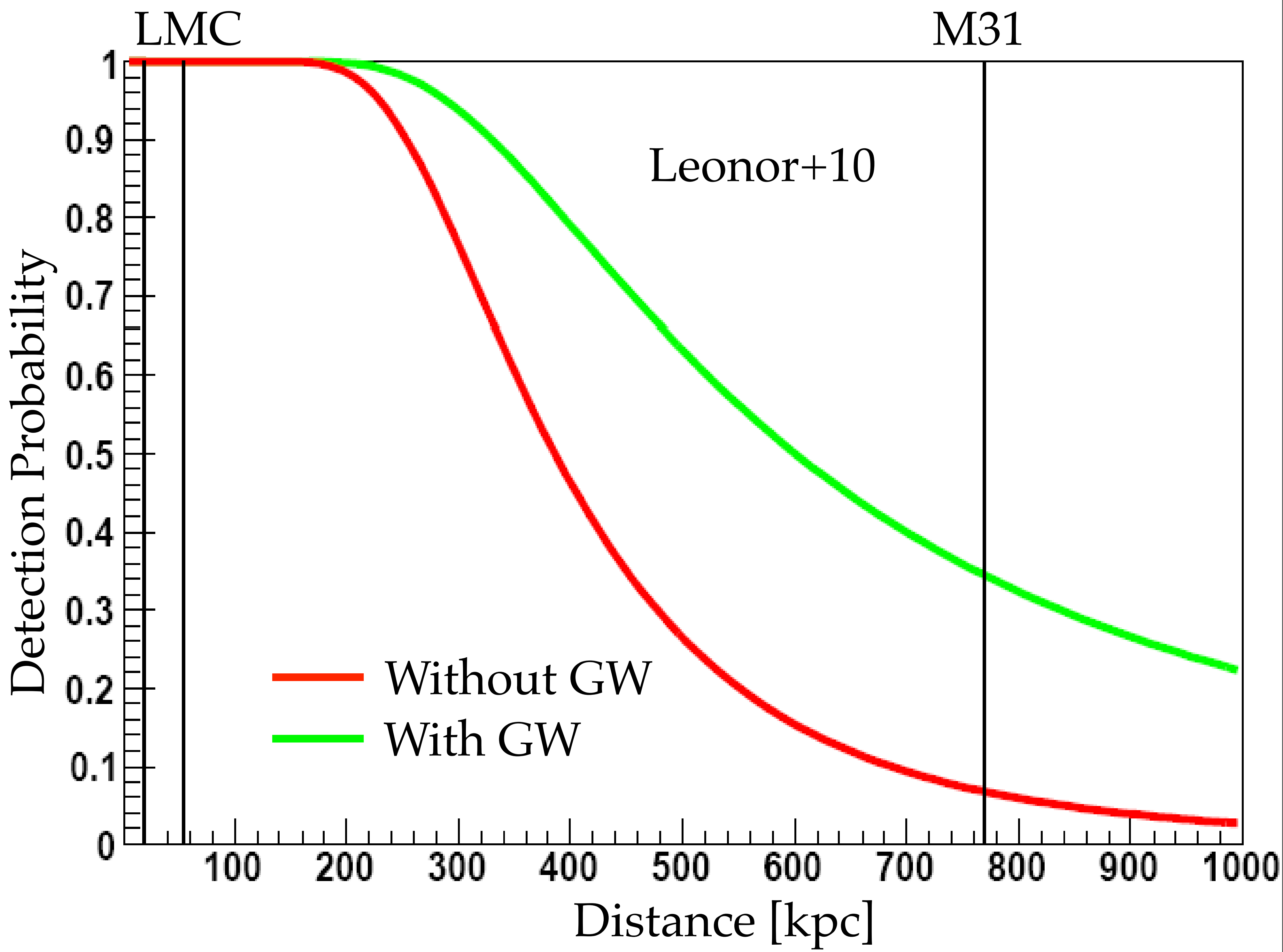
Detecting CCSNe with aLIGO



- Unlikely to detect average CCSNe beyond Milky Way/LMC/SMC.
- Non-detections make statements about progenitors.
- Sub-threshold signals in GW and neutrinos - combine to increase observational evidence.

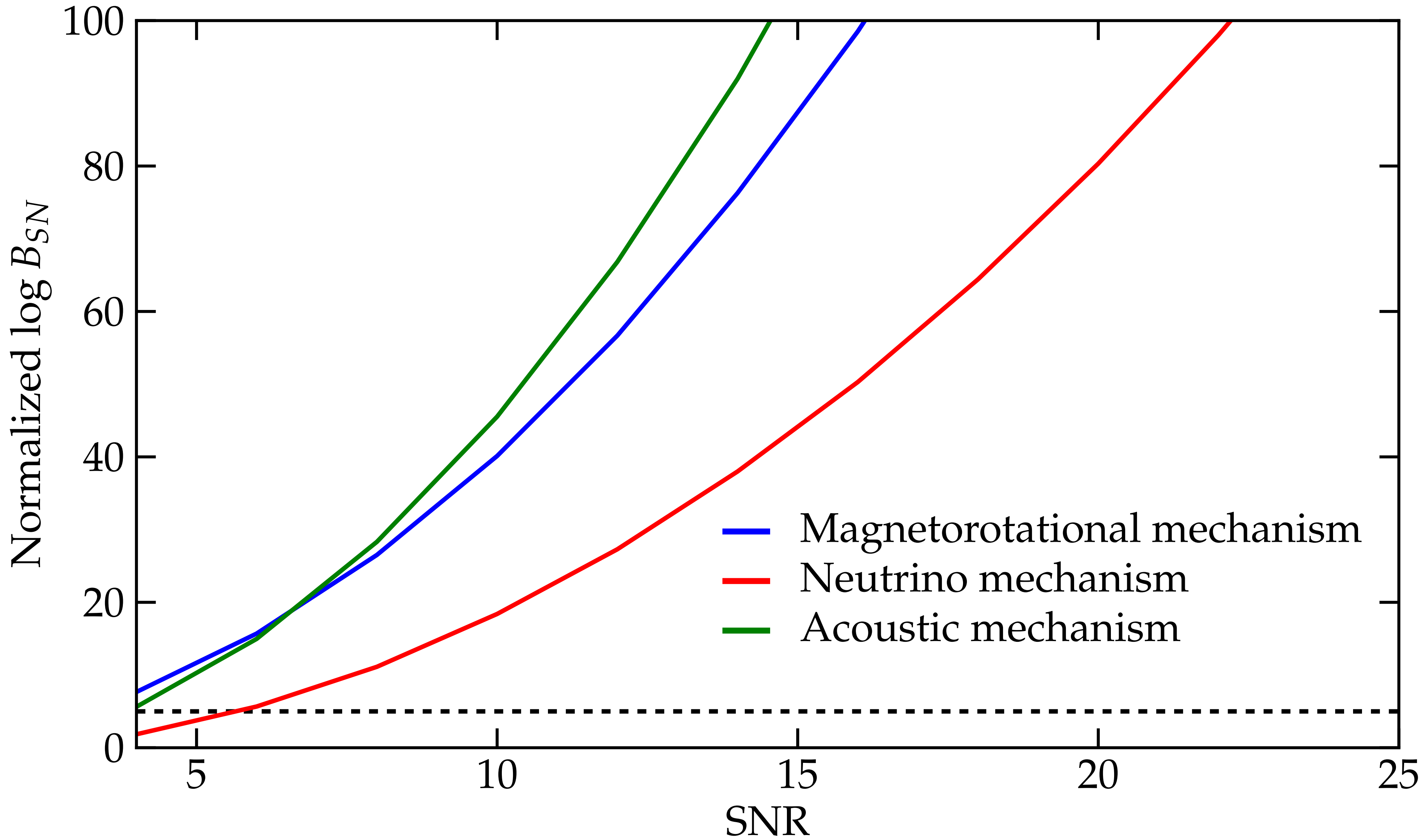
Utilizing sub-threshold GW/ν signals

- GRB051103.
- Estimate noise background.
- Exclude GW emission models.
- Improve neutrino search sensitivity - require GW coincidence.



Parameter Estimation for CCSNe

- Want astrophysically interesting information from observations.
- Don't have exact analytical expressions - Principal Component Analysis (PCA) captures dominant signal features.



- Reconstruct low SNR signals. Röver+09.
- Determine CCSN explosion mechanism. Logue+12.

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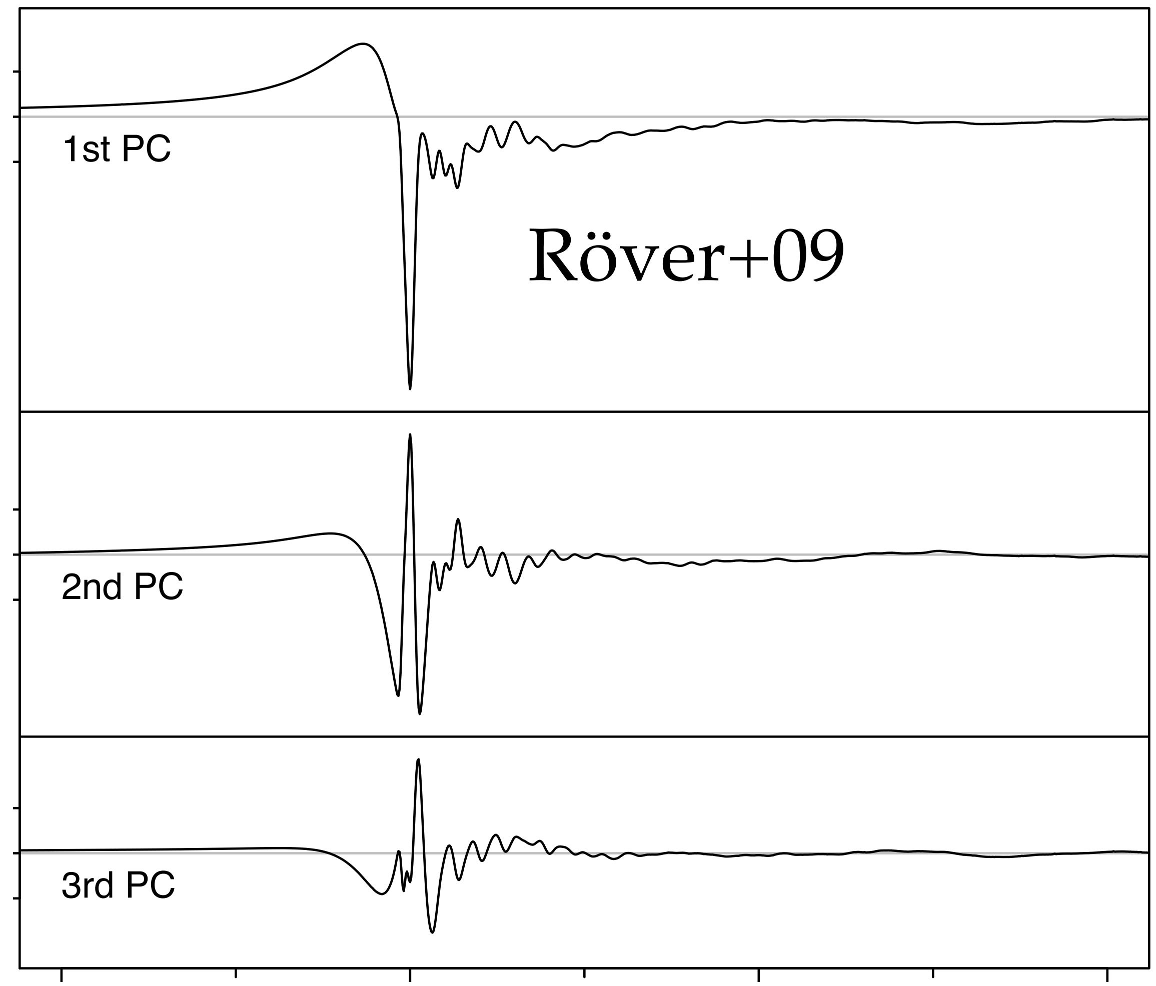
PCA and Bayesian Inference

- PCA - create basis sets encompassing \`principal components' of simulation waveform space.
- Generate PCs from time-domain, linearly polarized waveforms.
- Bayesian Inference with Nested Sampling algorithm.
  - PE: Estimate PC coefficients and reconstruct injected signals using PCs.
  - Model Selection: calculate evidence for each model - which PC set is most likely given observed data?



Posterior

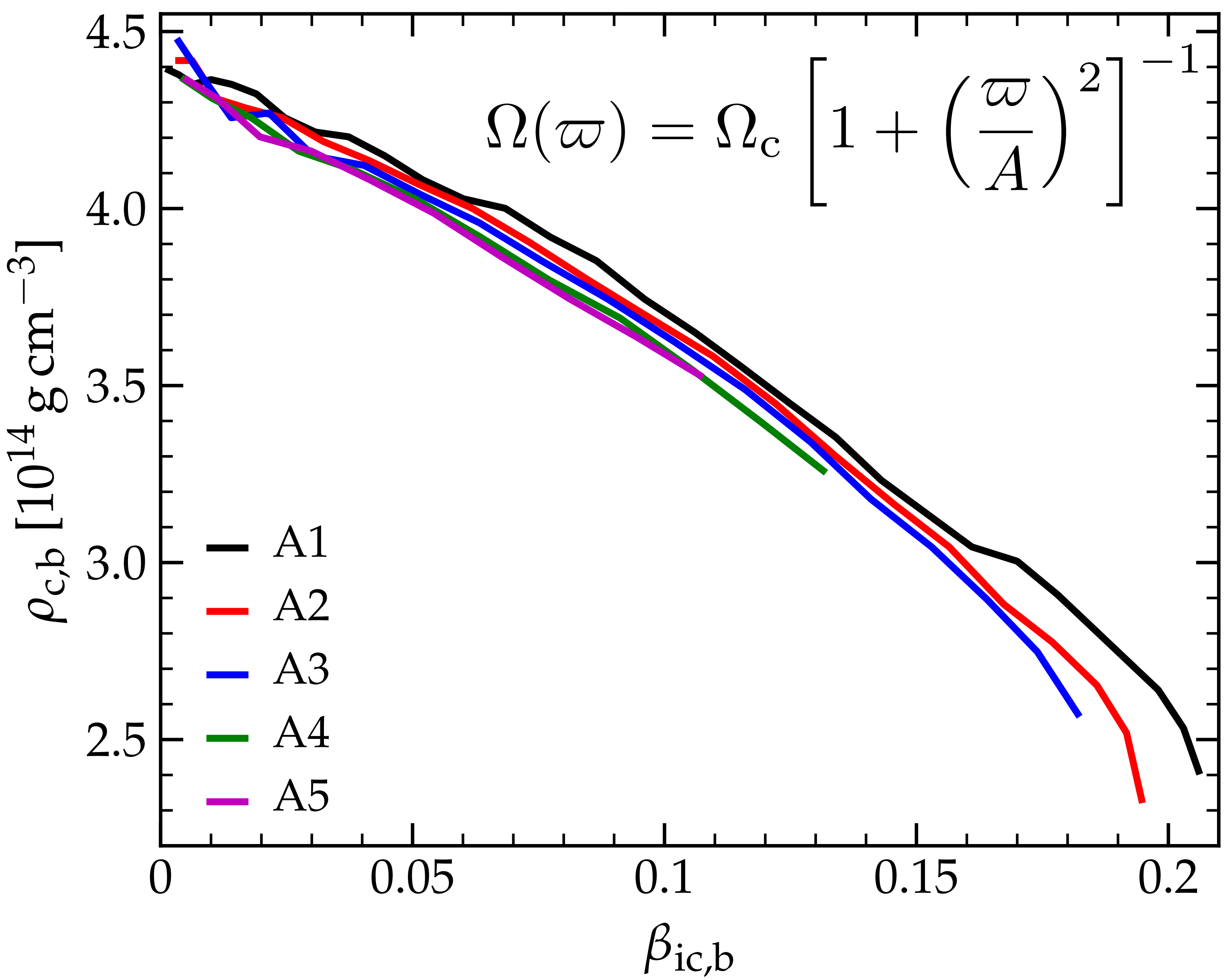
$$p(\theta|d,H) = \frac{p(d|\theta,H)p(\theta|H)}{p(d|H)}$$

Evidence

Inferring the Differential Rotation of CCSN Progenitors

Ernazar Abdikamalov, Sarah Gossan, Alexandra DeMaio, Christian Ott

- Characterize progenitor rotation for rotating core-collapse sources.
- Optimal-orientation and source at 10kpc - Only A and $\beta_{ic,b}$ unknown.
- Two approaches
  - Model selection.
  - Numerical template bank.



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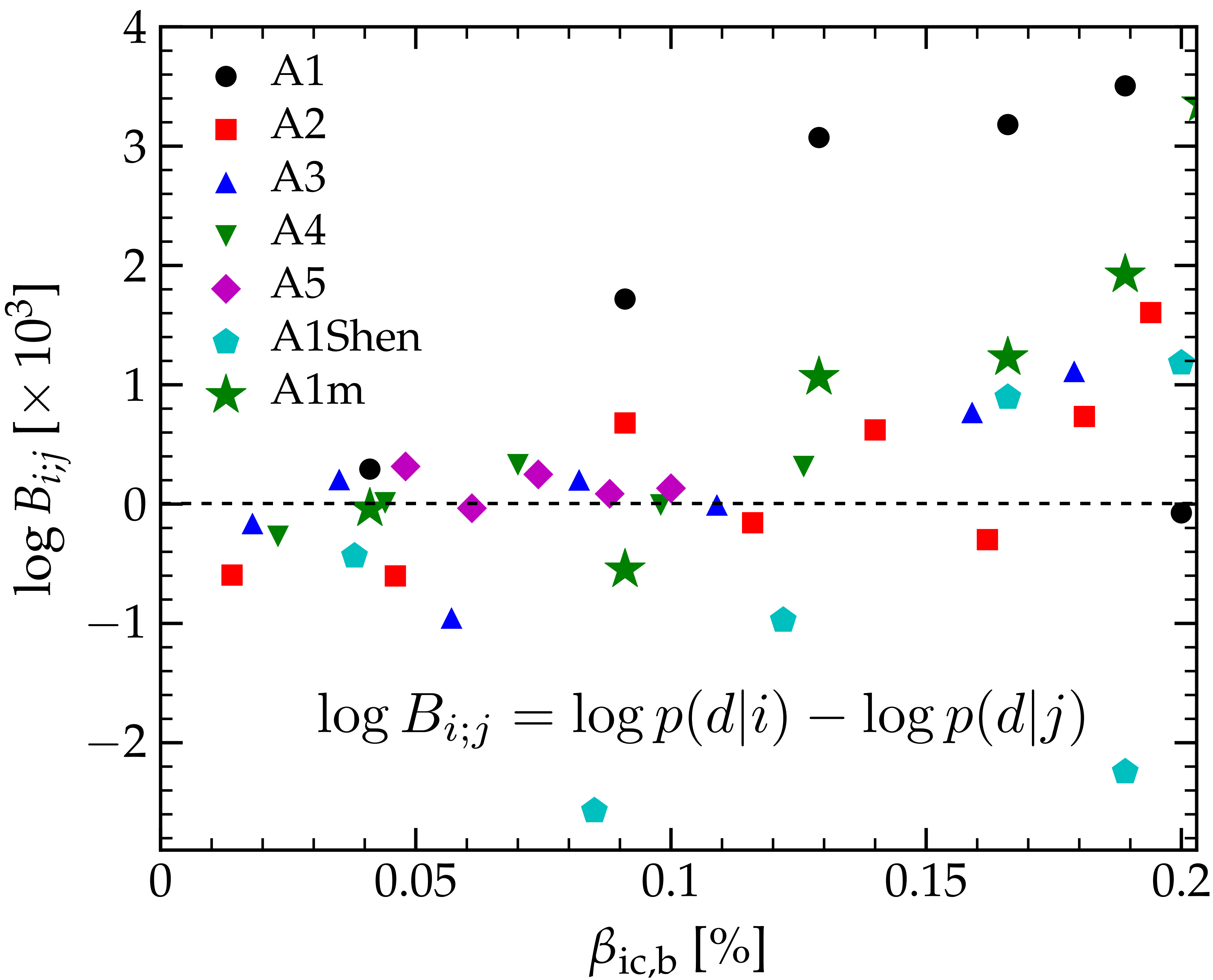
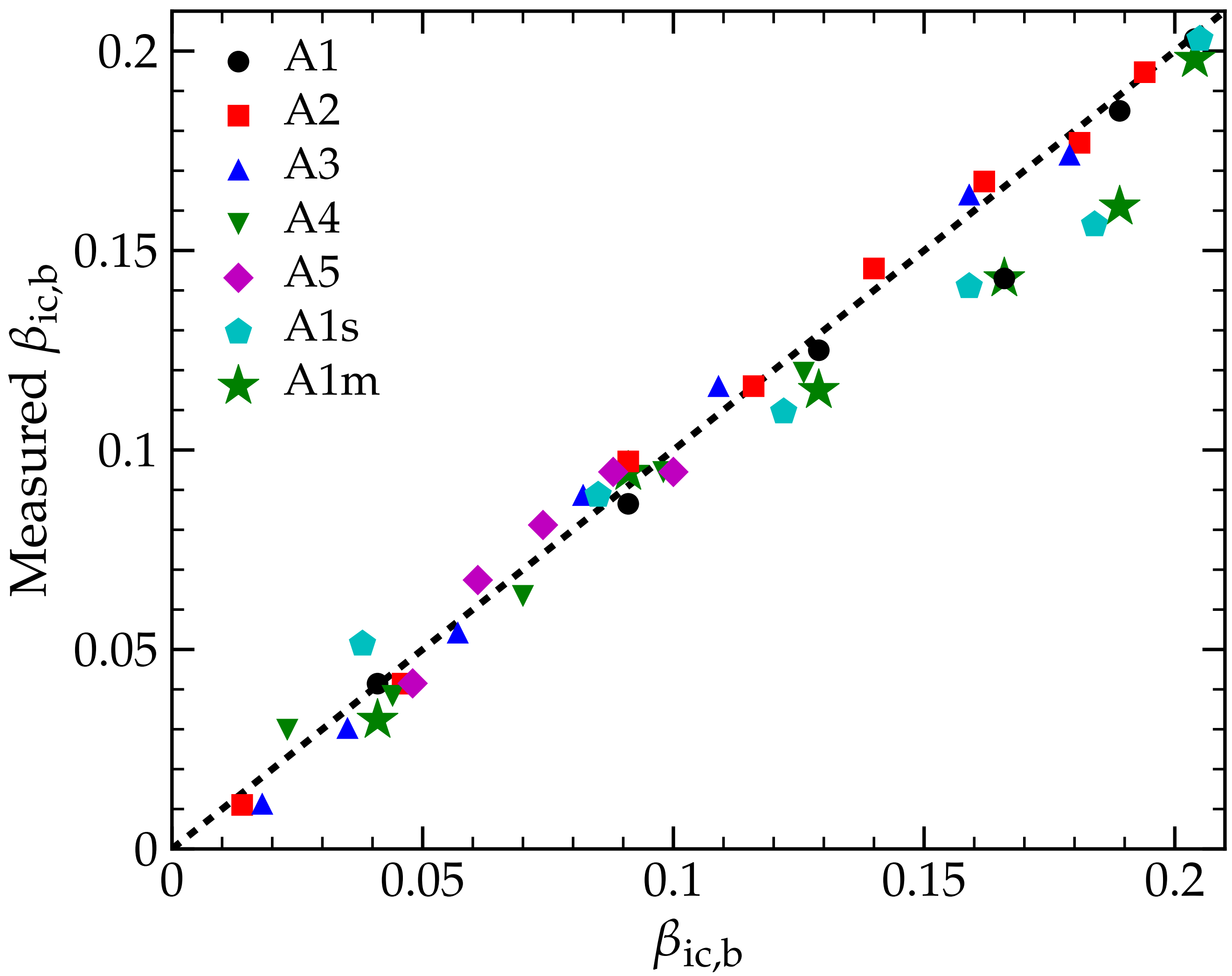
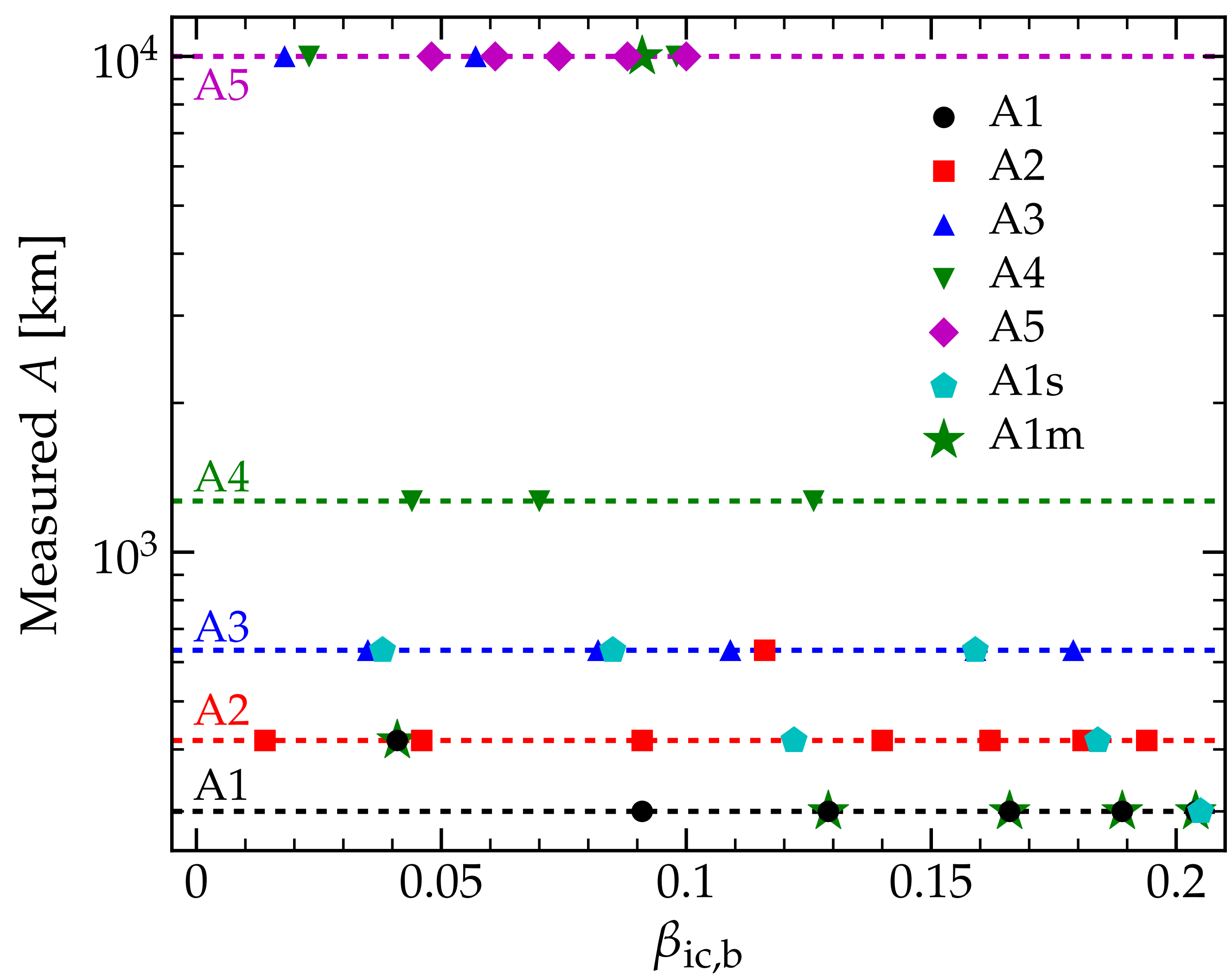
Determining A with Model Selection



A Numerical Template Bank - Matched Filtering





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Future Work

- Prepare for the first detection of GW from CCSNe!
  - More collaboration between GW and ν working groups.
  - Low-latency burst pipelines.
  - Real-time signal analysis.
  - Extend differential rotation analysis to additional physical progenitor parameters, e.g.different explosion mechanisms, equation of state.
- Inference analysis for both GW and ν signatures of CCSNe.